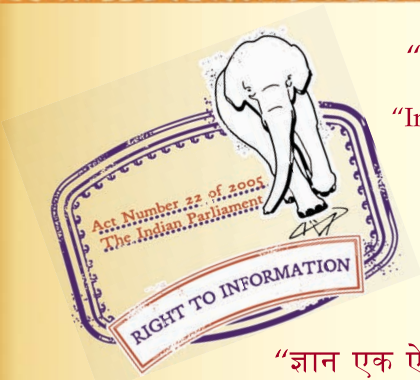
IS 9077 (1979): Code of practice for corrosion protection of steel reinforcement in RB and RCC construction [MTD 24: Corrosion Protection]



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Indian Standard

CODE OF PRACTICE FOR CORROSION PROTECTION OF STEEL REINFORCEMENT IN RB AND RCC CONSTRUCTION

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CODE OF PRACTICE FOR CORROSION PROTECTION OF STEEL REINFORCEMENT IN RB AND RCC CONSTRUCTION

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Indian Standard
CODE OF PRACTICE FOR CORROSION PROTECTION OF STEEL REINFORCEMENT IN RB AND RCC CONSTRUCTION

0. FOREWORD

0.1 This Indian Standard was adopted by the Indian Standards Institution on 30 January 1979, after the draft finalized by the Corrosion Protection Sectional Committee had been approved by the Structural and Metals Division Council.

0.2 The National Buildings Organization of Government of India had entrusted a research scheme on Corrosion of Reinforcement in Reinforced Brick (RB) and Reinforced Cement Concrete (RCC) to the Central Electro-Chemical Research Institute, Karaikudi in order to investigate the causes leading to corrosion and to evolve suitable preventive measures. The Institute conducted the research work during the years 1960 to 1967 and also carried out a survey of deteriorated reinforced brick and reinforced concrete structures at different places in the country.

0.2.1 This code has emerged as a result of the investigations carried out and the recommendations made by CECRI for Corrosion Prevention of Steel Reinforcement in their report.

0.3 This code has been prepared to provide a better understanding of the mechanism of reinforcement corrosion for the benefit of practising engineers, architects and builders engaged in the planning and execution of work involving reinforced brick and reinforced cement concrete construction. Adoption of preventive measures recommended in the code would enable substantial economies to be achieved by increasing the durability of the construction.

0.4 Stray current corrosion, which may also contribute to corrosion of steel reinforcement has not been considered in this code. It was also decided to defer recommending the use of galvanized reinforcement rods, until conclusive data on its use become available.

0.5 This standard should be read in conjunction with IS : 456-1978*.

*Code of practice for plain and reinforced concrete (*third revision*).

0.6 For rounding off the final value, observed or calculated, expressing the result of a test or analysis, IS : 2-1960* should be followed. The number of significant places retained in the rounded off value should be the same as that of the value given in this standard.

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1. SCOPE

1.1 This standard deals with the protection of reinforcement from corrosion in reinforced brick (RB) and reinforced cement concrete (RCC) construction.

2. TERMINOLOGY

2.1 For the purpose of this standard, the definitions given in IS : 3531-1969† shall apply.

3. ELECTRO-CHEMICAL BEHAVIOUR OF STEEL IN CONCRETE

3.0 The tendency of steel reinforcement to corrode or not to corrode in an environment like concrete may be expressed in terms of the electrical potential of steel with respect to the environment.

3.1 Effect of Alkalinity of Concrete on Steel — Most cement mortars and concrete are highly alkaline and the potential of steel in alkaline solution is positive, the steel being maintained in a passive condition.

3.1.1 Alkalinities of extracts from 1 : 2 cement sand mortar and M150 cement concrete are given in Table 1. The alkalinity ranges between 0·05 N and 0·06 N and is produced by the liberation of free lime and free alkali during setting of mortar and cement concrete. It is likely to fall with passage of time due to gradual carbonation of free lime, and the alkalinity in concrete, brought about by free alkali, may only remain. Therefore, an alkalinity of 0·04 N is assumed in M150 cement concrete, which is normally used in reinforced concrete construction.

3.1.2 Alkalinity of 0·04 N, obtained in M150 cement concrete, is sufficient to maintain the passivity of the reinforcement, but the immunity may be lost if the leachate from the concrete contains appreciable amounts of sulphate and chloride.

3.2 Effect of Chloride and Sulphate on Steel — The potential of steel in a solution containing sodium chloride or sodium sulphate is negative and

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*Rules for rounding off numerical values (*revised*).

†Glossary of terms relating to corrosion of metals.

the steel corrodes freely in these solutions. Introduction of these salts in the alkaline solution breaks down the passivity of steel obtained in alkaline medium, and the positive potential becomes negative.

3.2.1 In case of steel embedded in M150 concrete, the positive potential of steel is found to become negative in the presence of a few hundred parts per million of sodium chloride in the water in which concrete is dipped (*see* Table 2).

3.2.2 The concentration of chlorides and sulphates necessary to make the alkaline medium obtained in reinforced concrete work corrosive are given in Table 2. Alkalinity, which is likely to be had in set M150 cement concrete is inhibitive when the maximum content of chlorides only is 130 ppm and the maximum content of sulphates only is 2750 ppm. In the presence of 500 ppm of sulphates and 100 ppm of chlorides, the concrete with 0·04 N alkalinity remains inhibitive. Beyond these limits, the environment around M150 reinforced concrete becomes corrosive.

3.2.3 It is observed that water extracts of fresh cements are corrosive, whereas water extracts of powdered set cement are mostly non-corrosive. This is explained by the fact that the chlorides and sulphates present in fresh cement make the extract corrosive and that during setting of cement, chlorides and sulphates react with aluminate present in the cement and only a small fraction of the chloride or sulphate is left free. On an average, the chloride contents decrease to one-fifth and sulphate centents to one-tenth of their original values.

3.2.4 Simultaneous with the fall in alkalinity due to gradual carbonation of free lime in set cement concrete, even the same concentrations of chloride and sulphate render the environment more corrosive. Further, during the course of time as more and more chloride and sulphate diffuse into the concrete, the environment around steel reinforcement becomes more and more corrosive. A stage may be reached when the passivity of steel reinforcement breaks down at points where chloride or sulphate is able to attack the steel and the steel is gradually covered by corrosion product. The depth to which the reinforcement is attacked depends upon the duration for which each point of attack or pit is active, which in turn shall depend on the alternate wetting or drying of the concrete.

4. FACTORS INFLUENCING CORROSION OF REINFORCEMENT

4.1 Reinforcement corrosion in reinforced brick and reinforced cement, concrete construction takes place, when corrosive salts, for example chlorides and sulphates, increase beyond a critical limit and sufficient alkalinity is not obtained within the concrete to maintain steel in a passive condition.

TABLE 1 ALKALINITIES OF AQUEOUS EXTRACTS FROM CEMENT SAND MORTAR OF 1 : 2 MIX AND M150 CONCRETE MIX

(*Clause* 3.1.1)

SL No.	RATIO OF CEMENT/SAND OR CEMENT/SAND/ AGGREGATES	CaO (PERCENTAGE, ON IGNITED RESIDUE BASIS)	ALKALIES AS Na_2O (PERCENTAGE, ON IGNITED RESIDUE BASIS)	ALKALINITY
(1)	(2)	(3)	(4)	(5)
i)	Cement sand mortar (1 : 2) using river sand	37·7	60·5	0·05N
ii)	Cement sand mortar (1 : 2) using sea sand	14·9	69·4	0·06N
iii)	Cement sand mortar (1 : 2) using standard sand (Ennore)	31·1	66·5	0·05N
iv)	Concrete (M150) mix using river sand	49·6	51·0	0·06N
v)	Cement concrete (M150) mix using sea sand	32·7	53·4	0·06N
vi)	Cement concrete (M150) mix using standard sand (Ennore)	37·8	58·6	0·06N

4.1.1 Corrosion of reinforcement results in the formation of rust which occupies a much larger volume than the steel from which it is formed. This corrosion product exerts large internal pressure resulting in cracks and spalling in concrete. The formation of cracks in concrete further leads to quicker rate of corrosion, due to ingress of moisture and air resulting in failure of structures in due course.

4.2 The following factors are also responsible for corrosion of steel reinforcement in reinforced brickwork and reinforced cement concrete work:

a) *Quality of Concrete* — Concrete consists of coarse aggregate, fine aggregate, cement and water. The right quality of materials with proper water/cement ratio, correct mixing, adequate compaction by tamping or vibration and proper curing, results in good quality concrete. Dense concrete rich in cement content is impervious to a large degree and generally resists the corrosion of embedded steel.

b) *Cover Thickness of Concrete Over Reinforcement* — The reinforcement is protected by the concrete cover over it. The greater the cover thickness, more is the degree of protection against the various climatic and other environmental conditions. For various structural members, the cover thickness should be different depending upon their importance and degree of exposure. Evenness of the cover over the reinforcement is also very important for its corrosion protection.

c) *Condition of the Reinforcement* — The surface condition of the steel reinforcement, at the time of its placing in concrete, affects its corrosion rate. If the reinforcement is contaminated with salt or badly corroded, the corrosive action on reinforcement after placement in concrete is aggrevated and promoted rapidly.

TABLE 2 TOLERABLE LIMITS FOR CHLORIDE AND SULPHATE SALTS IN ALKALINE SOLUTION

(*Clauses* 3.2.1 *and* 3.2.2 and *Appendix* A)

Normality	Inhibitive	Corrosive
(1)	(2)	(3)
0·01N–NaOH	5 ppm Cl	6 ppm Cl
0·01N–NaOH	20 ppm SO_3	22·5 ppm SO_3
0·02N–NaOH	60 ppm Cl	65 ppm Cl
0·02N–NaOH	170 ppm SO_3	175 ppm SO_3
0·04N–NaOH	130 ppm Cl	150 ppm Cl
0·04N–NaOH	2750 ppm SO_3	2900 ppm SO_3
0·06N–NaOH	225 ppm Cl	250 ppm Cl
0·06N–NaOH	3250 ppm SO_3	3300 ppm SO_3
0·08N–NaOH	375 ppm Cl	400 ppm Cl
0·08N–NaOH	7200 ppm SO_3	7300 ppm SO_3
0·10N–NaOH	575 ppm Cl	600 ppm Cl
0·10N–NaOH	13250 ppm SO_3	13500 ppm SO_3
0·02N–NaOH 100 ppm SO_3	50 ppm Cl	55 ppm Cl
0·04N–NaOH 500 ppm SO_3	100 ppm Cl	105 ppm Cl
0·06N–NaOH 1000 ppm SO_3	175 ppm Cl	200 ppm Cl
0·06N–NaOH 1250 ppm SO_3	24 ppm Cl	27 ppm Cl
0·06N–NaOH 2500 ppm SO_3	12 ppm Cl	15 ppm Cl
0·06N–NaOH 3000 ppm SO_3	—	5 ppm Cl

5. MEASURES RECOMMENDED FOR PREVENTING REINFORCEMENT CORROSION

5.1 Controlling the Quality of Concrete and Composition of Raw Concrete Mix

5.1.1 *Quality of Concrete* — The grade of cement concrete should be M150 or higher for reinforced concrete work. The concrete should be properly compacted by tamping or vibration and adequately cured. The reinforced concrete may be rendered with cement plaster of 1 : 2 or 1 : 3 proportion. The rendering should be done only after the structure is passed and accepted for quality and finish.

5.1.1.1 Calcium chloride should not be used as far as possible for accelerating the setting and hardening of cement concrete, as this may accelerate corrosion of the reinforcement in all mixes of concrete.

5.1.1.2 Sea sand should not be normally used in RCC work. If there is no alternative, sea sand shall be washed free of chloride and sulphate before use.

5.1.2 *Sulphate and Chloride Content of Raw Concrete Mix* — Cement, sand, stone aggregates and water, should be tested for chloride and sulphate contents, as corrosion of the reinforcement bar is likely to occur if the total water soluble chloride and sulphate contents exceed the limits of 50 ppm and 500 ppm respectively in raw M150 concrete mix (*see* Appendix A). If such cases a protective coating on the bars may be necessary.

5.2 Provision of Adequate Cover Thickness to Steel Reinforcement

5.2.1 *Cover Thickness* — The thickness of cover on concrete reinforcement should be as follows:

a) *At each end of reinforcing bar* — Not less than 25 mm, nor less than twice the diameter of the bar.

b) *For a longitudinal reinforcing bar in a column* — Not less than 40 mm, nor less than the diameter of such rod or bar. In the case of columns of minimum dimension of 20 cm or under, the reinforcing bars of which do not exceed 13 mm, a cover of 25 mm may be used.

c) *For longitudinal reinforcing bars in a beam* — Not less than 25 mm nor less than the diameter of the rod or bar.

d) *For tensile, compressive, shear or other reinforcement in a slab* — Not less than 13 mm nor less than the diameter of such reinforcement.

e) *For any other reinforcement* — Not less than 13 mm nor less than the diameter of such reinforcement.

5.2.2 Increased cover thicknesses should be provided when surfaces of concrete members are exposed to the action of harmful chemicals, acids, vapours, saline atmosphere, sulphurous smoke (as in case of steam operated railways), etc. The increase in cover thickness may be between 15 mm and 40 mm beyond the figures given in **5.2.1** but the total cover thickness should not exceed 50 mm.

5.2.3 For reinforced concrete members, totally or periodically immersed in sea water or subject to salt spray, the cover should be 50 mm.

5.2.3.1 Concrete cover of more than 50 mm is not recommended as it may give rise to increase crack widths which may further allow direct ingress of deleterious materials to the reinforcement. It may, however, be noted that IS: 456-1978* does not impose any such limitation on cover thickness. In case of reinforced concrete members in areas exposed to the action of harmful chemicals or sea water, it is desirable to use richer mixes of concrete, like grade M200 or M250.

5.3 Protective Coatings on Concrete Cover and Reinforcement

5.3.1 *Protective Coating on Concrete* — Existing RCC structures may be protected from reinforcement corrosion in aggressive atmospheres by applying protective surface coatings to the exposed surfaces of concrete.

5.3.1.1 *Cement-sand-asphalt/coal tar pitch mixture coating* — The dry concrete surface should be roughened by chiselling. A mixture of dry cement, molten asphalt or coal tar pitch and dry sand in the ratio 1 : 1 : 3 by weight, should be applied on the dry concrete surface by trowelling to a thickness of 6 mm and the surface should be finished by flaming.

5.3.1.2 *Cement-sand-mortar with neat cement finish* — Dry concrete surface should be roughened by chiselling and a workable mixture of 1 : 3 cement sand mortar should be applied on the concrete surface, after water in the surface properly, by trowelling to a thickness of 6 mm. The surface should be finished with a neat cement slurry consisting of water and cement in the ratio 2 : 1.

5.3.1.3 Epoxy coating or epoxy mortar rendering may also be applied to existing structures for better performance.

5.3.2 Steel reinforcement for RB and RCC work should be free from loose rust and salts which are likely to be present in marine atmosphere. Slight rust may be removed by rubbing the rod with gunny cloth. Heavy rusting of reinforcement should be removed by wire brushing or application of commercially produced derusting and phosphating jellies of approved quality. It should, however, be ensured that no oil or paint is applied as a protective coating to the reinforcement bar.

5.3.3 *Protective Coating of Reinforcement Bars* — Since it may not be possible to restrict the chloride and sulphate content within the tolerable limits in marine atmospheres or in contact with sea water, the reinforcement bars should be coated with a protective coating of inhibited cement slurry. One method adopted for application of such type of coating is given in Appendix 'B' for guidance only.

5.4 Proper Design and Construction of Roofs

5.4.1 *Type of Bricks Used in Reinforced Brick Construction* — Reinforced brick work should not be used for roofing of permanent buildings as the bricks have a greater tendency to gather moisture including salts which

*Code of practice for plain and reinforced concrete (*third revision*).

corrode the reinforcement. Roofing with precast RCC battens and brick filling or hollow clay blocks may be adopted with advantage. The minimum cover thicknesses should be 25 mm of M150 cement concrete.

5.4.1.1 Machine-made or hollow blocks wherever available are preferable to hand-moulded bricks. Reinforced brick work may be used with caution in intermediate slabs of construction which are protected from water and rain as well as direct approach of moisture. Care should be taken to see that the reinforcement in reinforced brick work is protected by a minimum cover thickness of 25 mm of M150 cement concrete or 1 : 2 cement mortar.

5.4.1.2 Reinforced brick slab shall not be adopted in marine or other aggressive atmospheres.

5.4.2 *Roof Design* — Flat roofs should be designed to have adequate slope so that rain water flows off quickly without stagnating and penetrating into roof slab. The top of the roof slab should be finished even and smooth with a trowel before the concrete begins to set. The exposed surfaces of RCC work should be rendered smooth with 1 : 3 cement mortar. Further the tops of the roofs should be painted with a coat of bitumen or provided with other water-proofing material, such as alkathene film with a layer of lime concrete or mud-phuska and tiles laid over on top.

APPENDIX A

(*Clause* 5.1.2)

METHOD USED FOR CALCULATING THE PERMISSIBLE CHLORIDE AND SULPHATE CONTENT OF RAW CONCRETE MIX

A-1. The maximum permissible chloride content of raw concrete mix is calculated on the basis of the critical amount of sulphate and chloride in capillary water, beyond which the passivity of the reinforcement in the alkaline medium, obtained in set concrete, is not maintained.

A-2. An alkalinity of 0·04N is likely to be maintained in set grade M150 concrete. Therefore, the maximum tolerable values of chloride and sulphate content for corrosion inhibition would be 100 ppm and 500 ppm respectively in capillary water (*see* Table 2).

A-3. Assuming that the average porosity for water permeation of grade M150 cement concrete is 10 percent, the maximum permissible limits of chloride and sulphate content in set cement concrete work out to 10 ppm and 50 ppm respectively.

A-4. It has been observed experimentally that on an average, the chloride content decreases to one-fifth and the sulphate content decreases to one-tenth of their original values, during setting of the cement concrete. The maximum permissible limits for raw concrete mix, therefore, works out to 50 ppm of chloride and 500 soluble ppm of sulphate respectively.

APPENDIX B

(*Clause* 5.3.3)

PROCEDURE FOR APPLICATION OF PROTECTIVE COATING OF REINFORCEMENT RODS

B-1. The reinforcement rods should be dipped in the derusting solution of approved quality and the rods removed as soon as the rust is satisfactorily removed and a bright surface is obtained. This should be immediately followed by cleaning the rods with wet waste cloth and alkaline cleaning powder. The rod should then be brushed with the phosphating jelly of approved quality by means of a fibre brush. The jelly should be left on the surface for a period of 45-60 minutes and then removed by means of wet waste cloth. This should be followed by brushing the inhibitor solution of approved quality and the first coat of cement slurry, prepared by mixing 500 cc of inhibitor solution for each 1 000 g of portland cement. All the above steps should be applied in the same day and after 12-24 hours of air-drying the sealing solution of approved quality should be brushed followed by the second coat of cement slurry. It should then be dried for 12-24 hours followed by a brush coat of the sealing solution which should be applied again after 4 hours of air-drying.

INDIAN STANDARDS

ON

CORROSION

IS:

3531-1968 Glossary of terms relating to corrosion of metals

3618-1966 Phosphate treatment of iron and steel for protection against corrosion

4180-1967 Code of practice for corrosion protection of light gauge steel sections used in building

4777-1968 Performance tests for protective schemes used in the protection of light gauge steel against corrosion

5555-1970 Code of procedure for conducting field studies on atmospheric corrosion of metals

6005-1970 Code of practice for phosphating of iron and steel

7808-1975 Code of procedure for conducting studies on underground corrosion of metals.

8062 (Part I)-1976 Code of practice for cathodic protection of steel structures: General principles

(Part II)-1976 Underground pipelines

(Part III)-1977 Ships' hulls

8221-1976 Code of practice for corrosion prevention of metal components in packages

8629 (Parts I to III)-1977 Code of practice for protection of iron and steel structures from atmospheric corrosion